GEOPHYSICAL SURVEYS
GROUND WATER EVALUATION
NEAR HUEHUE RANCH,
MAKALAWENA AREA
ISLAND OF HAWAII

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MAKALAWENA AREA
ISLAND OF HAWAII

Prepared For:

Kamehameha Schools/
Bernice Pauahi Bishop Estate
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Purchase Order No.: 9010882

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(Our Project #90015)

April 24, 1990

Table of Contents

1.0 INTRODUCTION

This report contains the results of a geophysical survey to assist the evaluation of fresh water resources near Huehue Ranch, Kiholo Quadrangle, on the Island of Hawaii. The specific area of interest was the Makalawena area. The work was performed by Blackhawk Geosciences, Inc. (BGI) for Kamehameha Schools/Bernice P. Bishop Estate (KS/BPBE) on April 1, 2 and 3, 1990.

The objectives for the geophysical survey can be understood from the hydrogeologic cross-section, typical of a volcanic island, shown in Figure 1-1. The volcanic rocks are generally highly permeable allowing rainfall to rapidly infiltrate into the ground and migrate downward to the water table, and eventually discharge into the ocean. Fresh water in these settings is found in two environments:

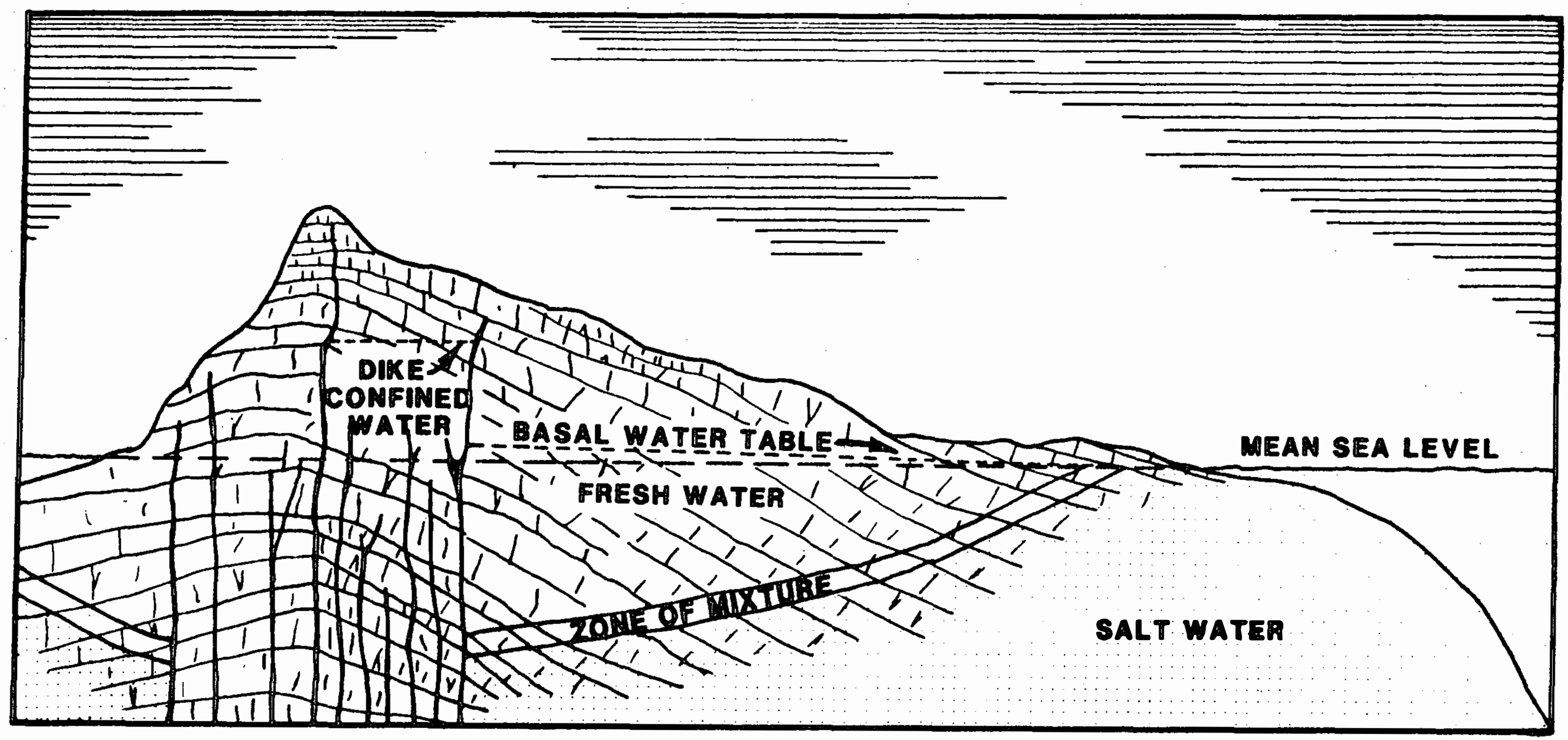
1. <u>Dike confined waters</u>. Above the rift zone intrusive dikes originating from a magma source below can form ground water dams, and behind these natural dams significant quantities of ground water can be stored.

2. <u>Basal fresh water</u>. The high permeability of the volcanic rocks allows sea water to enter freely under the island, and a delicate balance is reached where a lens of fresh water floats on sea water. The Ghyben-Herzberg relation states that for every foot of fresh water head above sea level there will be 40 ft of fresh water below sea level.

The basal water resource was the focus in the investigations for KS/BPBE. The drilling depth to the basal fresh water lens rapidly increases with elevation, and the objective of geophysical surveys is to determine the drilling depth to fresh water and the thickness of the fresh water lens. The impetus for using geophysics is that the cost of a geophysical station is about one-five-hundredth of the cost of drilling a well at elevations above 1,000 ft. Geophysical surveys, combined with other hydrogeologic information, are used to provide optimum locations for well placement and well completion depths.

The geophysical method employed was time domain electromagnetic (TDEM) soundings. This method was selected because it has proven effective in prior surveys in similar settings in Hawaii.

The specific objective of the geophysical survey over the Makalawena areas was to derive the thickness of the basal fresh water zone in the study area.



BLACKHAWK GEOSCIENCES, INC.

SCHEMATIC HYDRO-GEOLOGIC CROSS SECTION

Kamehameha Schools/Bishop Estate

Makalawena Mauka Project

PROJECT NO.: 90015 **FIGURE 1-1**

2.0 LOGISTICS AND DATA ACQUISITION

A brief description of the fundamentals of TDEM is given in Appendix A. Briefly, the logistics of a TDEM measurement consist of:

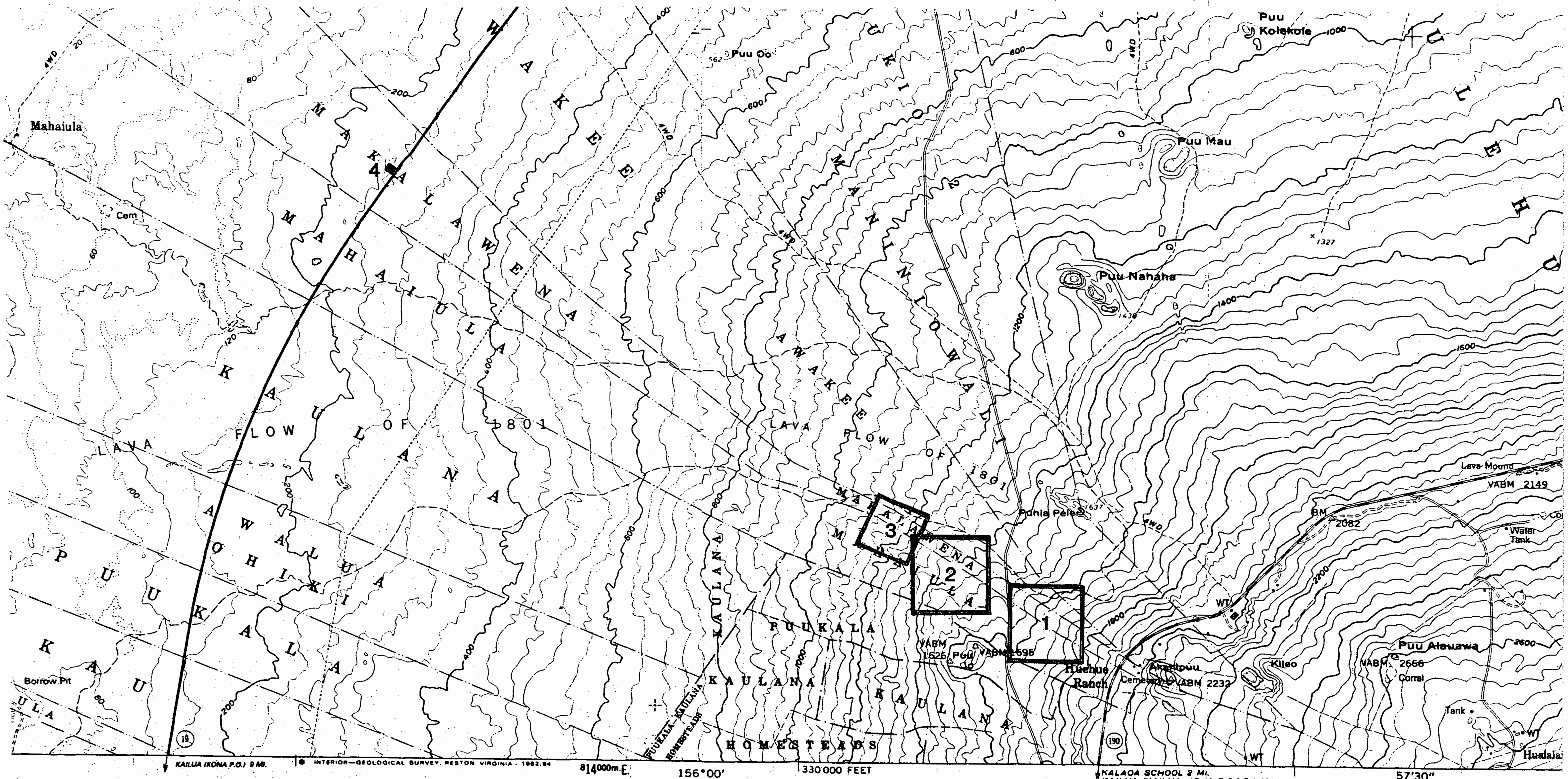
1. Laying out a square loop of insulated wire. A generator placed in the loop is used to drive current pulses through this closed loop. The dimensions of the square loops employed depend on the exploration depth requirements. The dimensions of the loops used for the survey were 1,500 ft by 1,500 ft on each side for loops 1 and 2, a 1,000 ft by 1,000 ft loop was used for loop 3, and a 150 ft by 150 ft loop was used for loop 4.

2. Making a measurement with a receiver in the center of the loop. The data acquired at each station was stored in the field on a solid state data logger and subsequently dumped to a computer at the end of each field day. The data acquired at each station usually consisted of measurements at several receiver gain settings and transmitter frequencies in order to assure data quality and to obtain data over the largest time range possible. Data quality was generally very good.

During the three days of field work four stations (soundings) were completed. A daily log of field activity is given in Table 2-1. Figure 2-1 shows the location of the soundings conducted for KS/BPBE.

Table 2-1. Daily log of field activities

Date (1990)	Activity
March 26	Mobilization of BGI personnel from Golden, CO to Kailua-Kona, HI.
March 27-31	Performed other geophysical surveys.
April 1	Recorded Loop 1 and Loop 4.
April 2	Recorded Loop 2.
April 3	Recorded Loop 3.
April 4-11	Performed other geophysical surveys.
April 12-13	Demobilize crew from Kailua-Kona, HI to Golden, CO.



Transmitter Loop

1500' x 1500'

1000' x 1000'

150' x 150'

N

1000 0 1000 2000 3000 4000

SCALE - FEET

BLACKHAWK GEOSCIENCES, INC.

TIME DOMAIN EM SURVEY
LOCATION MAP

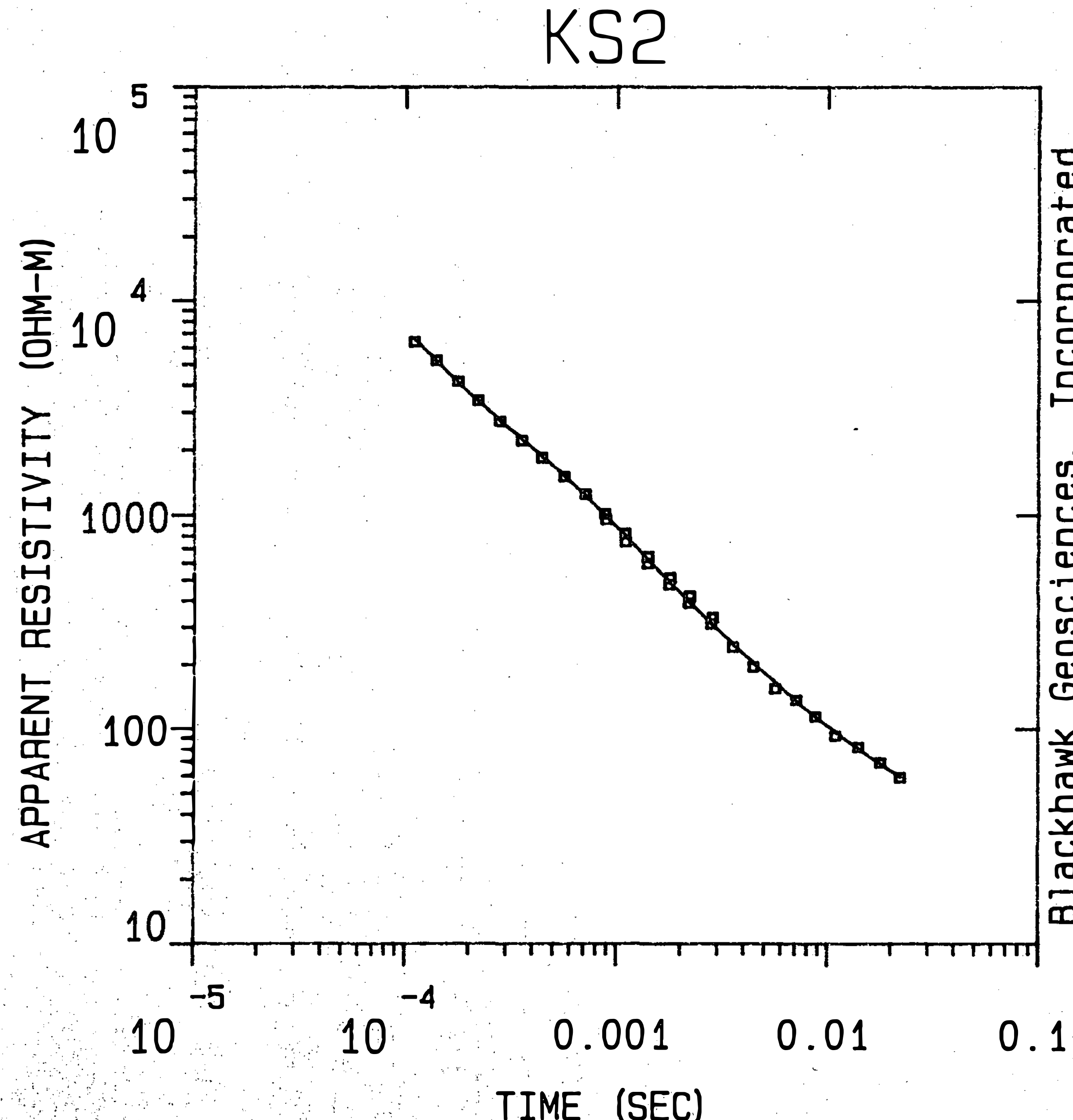
Kamehameha Schools/Bishop Estate
Makalawena Mauka Project

PROJECT NO.: 90015 FIGURE 2-1

3.0 DATA PROCESSING

The objective of data processing is to derive from the TDEM measurements in the center of the loop the resistivity layering in the earth. The procedures of data processing are discussed in Appendix A. The results from data processing for each station are contained in Appendix B. An example data set is given in Figures 3-1 and 3-2 for loop KS2. Figure 3-1 shows the measured data points (in terms of apparent resistivity) superimposed on a solid line. The solid line represents the computed behavior of the true resistivity layering shown on the right. Figure 3-2 lists in column 4 the error between measured and computed data in each time gate.

Figure 3-1 shows that the resistivity layering in the upper 2,100 ft consists of three layers. The first layer has a thickness of 418 m with a resistivity of greater than 1,000 ohm-m. The second layer has a thickness of 200 m and a resistivity of 128 ohm-m, and the third layer has a resistivity of 13.7 ohm-m. Loops 1, 2 and 3 were all interpreted with three-layer models. Loop 4, which lies along the main highway near the ocean, was interpreted with a two-layer model.



MODEL:

5466. OHM-M 418. M

128. OHM-M 200. M

13.7 OHM-M

BLACKHAWK GEOSCIENCES, INC.

EXAMPLE
APPARENT RESISTIVITY CURVE
SOUNDING 2

Kamehamaha Schools/Bishop Estate

PROJECT NO.: 90015 **FIGURE 3-1**

% ERROR: 5.49
CALIBRATION: 1
OFFSET: 229. M
RAMP: 260.0

MODEL: 3 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		423.7	1390.0		
5465.58	418.3	5.4	17.7	0.1	0.1
127.56	199.8	-194.4	-637.9	1.6	1.6
13.65					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	1.10E-04	1.61E-01	1.51E-01	6.302	
2	1.40E-04	1.19E-01	1.22E-01	-1.961	
3	1.77E-04	9.32E-02	9.55E-02	-2.491	
4	2.20E-04	7.33E-02	7.48E-02	-1.912	
5	2.80E-04	5.61E-02	5.57E-02	0.765	
6	3.55E-04	4.23E-02	4.14E-02	2.331	
7	4.43E-04	3.19E-02	3.14E-02	1.629	
8	5.64E-04	2.37E-02	2.34E-02	1.326	
9	7.13E-04	1.75E-02	1.81E-02	-3.123	
10	8.81E-04	1.41E-02	1.45E-02	-2.711	
11	8.90E-04	1.50E-02	1.44E-02	4.417	
12	1.10E-03	1.11E-02	1.16E-02	-4.195	
13	1.10E-03	1.26E-02	1.16E-02	8.500	
14	1.40E-03	9.72E-03	9.14E-03	6.285	
15	1.41E-03	8.51E-03	9.07E-03	-6.148	
16	1.77E-03	7.62E-03	7.25E-03	5.033	
17	1.80E-03	6.57E-03	7.16E-03	-8.117	
18	2.20E-03	5.97E-03	5.84E-03	2.122	
19	2.22E-03	5.18E-03	5.78E-03	-10.449	
20	2.80E-03	4.57E-03	4.55E-03	0.421	
21	2.85E-03	3.93E-03	4.47E-03	-12.021	
22	3.55E-03	3.68E-03	3.52E-03	4.571	
23	4.43E-03	2.92E-03	2.76E-03	5.931	
24	5.64E-03	2.29E-03	2.07E-03	10.354	
25	7.13E-03	1.52E-03	1.55E-03	-1.890	
26	8.81E-03	1.18E-03	1.18E-03	-0.328	
27	1.10E-02	9.33E-04	8.79E-04	6.179	
28	1.41E-02	5.97E-04	6.19E-04	-3.517	
29	1.80E-02	4.19E-04	4.32E-04	-2.972	
30	2.22E-02	3.11E-04	3.10E-04	0.311	

R: 229. X: 0. Y: 229. DL: 457. REQ: 254. CF: 1.0000
TDHZ ARRAY, 30 DATA POINTS, RAMP: 260.0 MICROSEC, DATA: KS2
0204 0002 0002 Z OPR XTL H 6 8+100
Ch.21 = 0.26 Ch.22 = 0.089 Ch.23 = 18.5 Ch.24 =
RMS LOG ERROR: 2.32E-02, ANTILOG YIELDS 5.4948 %
EARLY TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

	P 1	P 2	P 3	T 1	T 2
P 1	0.85				
P 2	-0.04	0.98			
P 3	0.00	0.00	1.00		
T 1	0.01	0.01	0.00	1.00	
T 2	-0.03	-0.01	0.00	0.00	0.99

BLACKHAWK GEOSCIENCES, INC.

EXAMPLE DATA SHEET
SOUNDING 2

Kamehameha Schools/Bishop Estate

PROJECT NO.: 90015 **FIGURE 3-2**

4.0 INTERPRETATION RESULTS

4.1 GENERAL

The objective of KS/BPBE and its ground water consultants is not to obtain the resistivity layering of the subsurface, but to infer from the resistivity information, the depth to salt water and the thickness of the basal fresh water lens. The translation of resistivity layering into hydrogeologic information is generally accomplished by using available knowledge about the relation between resistivity values and hydrogeology. For example, in the volcanic rocks of Hawaii, rocks saturated with salt water will have resistivities less than 5 ohm-m. On the other hand, dry volcanic rocks can have very high resistivities (greater than 1,000 ohm-m).

The results of the TDEM interpretations are presented as geoelectric and hydrogeologic sections in Figures 4-1 and 4-2.

4.2 GEOELECTRIC SECTION

In the geoelectric section (Fig. 4-1) layers with similar resistivities have been linked together. Beneath soundings 1, 2 and 3 a three-layer section is interpreted and the layering is shown on the geoelectric section.

In the geoelectric section the near surface layer (1317 to 3593 ohm-m) is interpreted to represent unsaturated and fresh/brackish water saturated volcanics. Generally, it is difficult to discriminate between a dry volcanic and fresh water zone or a brackish water (less than 500 ppm chloride) saturated volcanic zone. The reason is that, in addition to salinity, changes in porosity and lithology also influence formation resistivity, particularly at low values of chloride concentration. The second layer beneath soundings 2, 3 and 4 exhibits intermediate resistivities (128 to 241 ohm-m). These intermediate resistivities may be caused by one or more of the following factors

- alteration of volcanics
- increased salinity
- presence of clays or ash flows.

Due to the proximity of several Puu features in the area (Puu Io, Puu Nahaha) it is more likely that this intermediate layer is related to either alteration of the volcanics or ash flows and not to an increase in salinity.

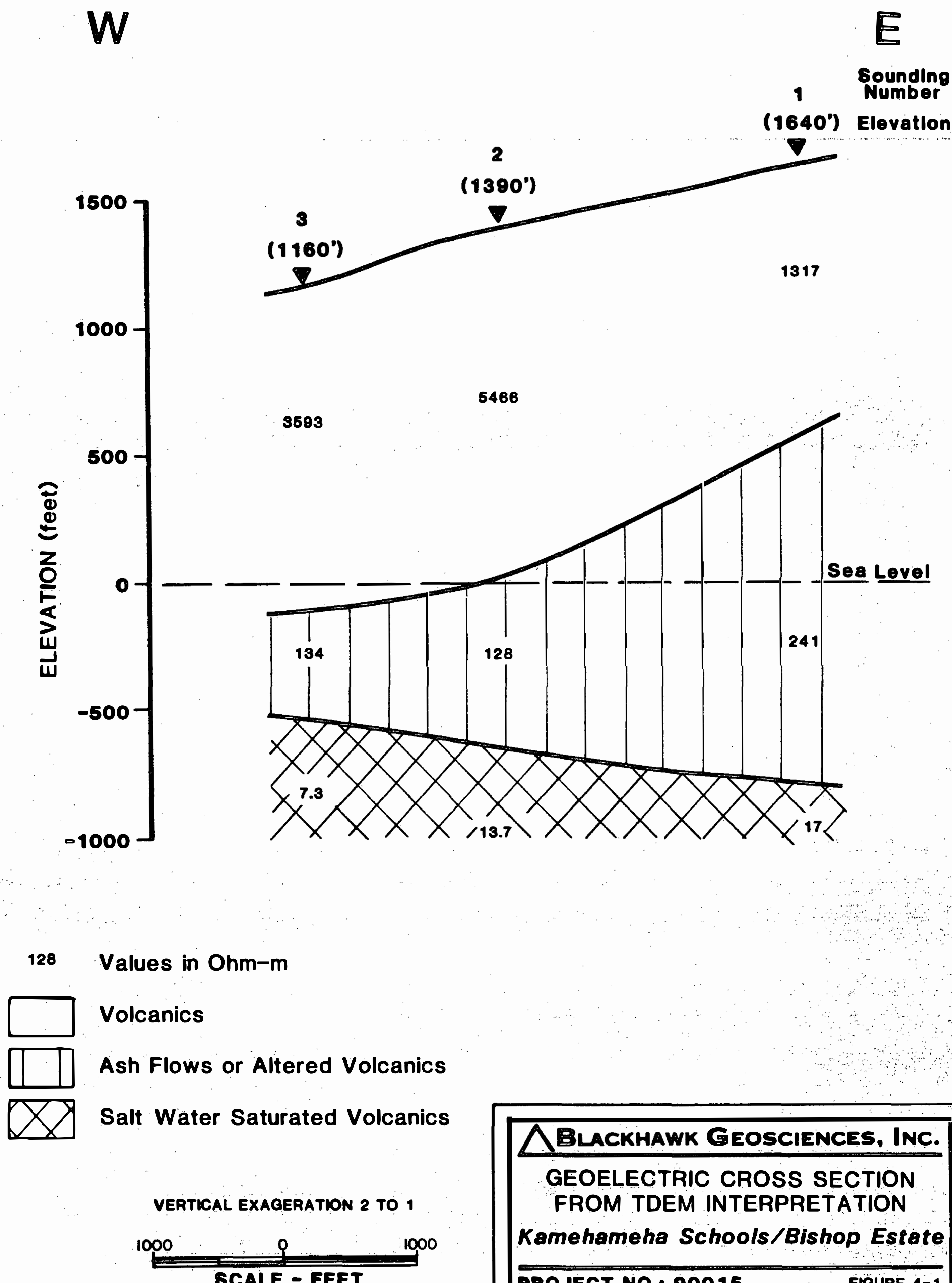
The lowest layer in the section (13.7 ohm-m and less) likely represents saline water saturated volcanics. To determine the resistivity of the saline water saturated volcanics, loop 4 was recorded along the main highway (Fig. 4-2), where the saline waters are relatively close to the surface. The resistivity calculated for saline saturated volcanics at loop 4 was 4 ohm-m. The low resistivity layer can be fixed at a calculated resistivity (4 ohm-m) for all soundings in the survey. In this study, fixing the lower layer resistivity at 4 ohm-m degraded the quality of the solutions for loops 1, 2 and 3. The best solutions for the models were obtained when the lower layer resistivity was not fixed, and all parameters were allowed to float. Table 4-1 shows the results for each sounding.

Table 4-1. Results of TDEM Survey

Sounding #	**Surface Elevation (ft)**	**Head of Fresh/Brackish Water Above Sea Level (Water Table) (ft)**	**Minimum Thickness of Fresh/Brackish Water Lens (ft)**
1	1640	19.2	787
2	1390	15.9	654
3	1160	13.3	546
4	240	.9	37.0

4.3 HYDROGEOLOGIC SECTION

In the hydrogeologic section (Fig. 4-2) the head of fresh/brackish water and thickness of the fresh/brackish water lens is shown. The bottom of the fresh/brackish water lens is obtained directly from the geoelectric section (Fig. 4-1), and the top of the fresh water lens (head) is calculated from the Ghyben-Herzberg relation. The thickest fresh/brackish water lens (787 ft) is interpreted to occur near sounding 1.



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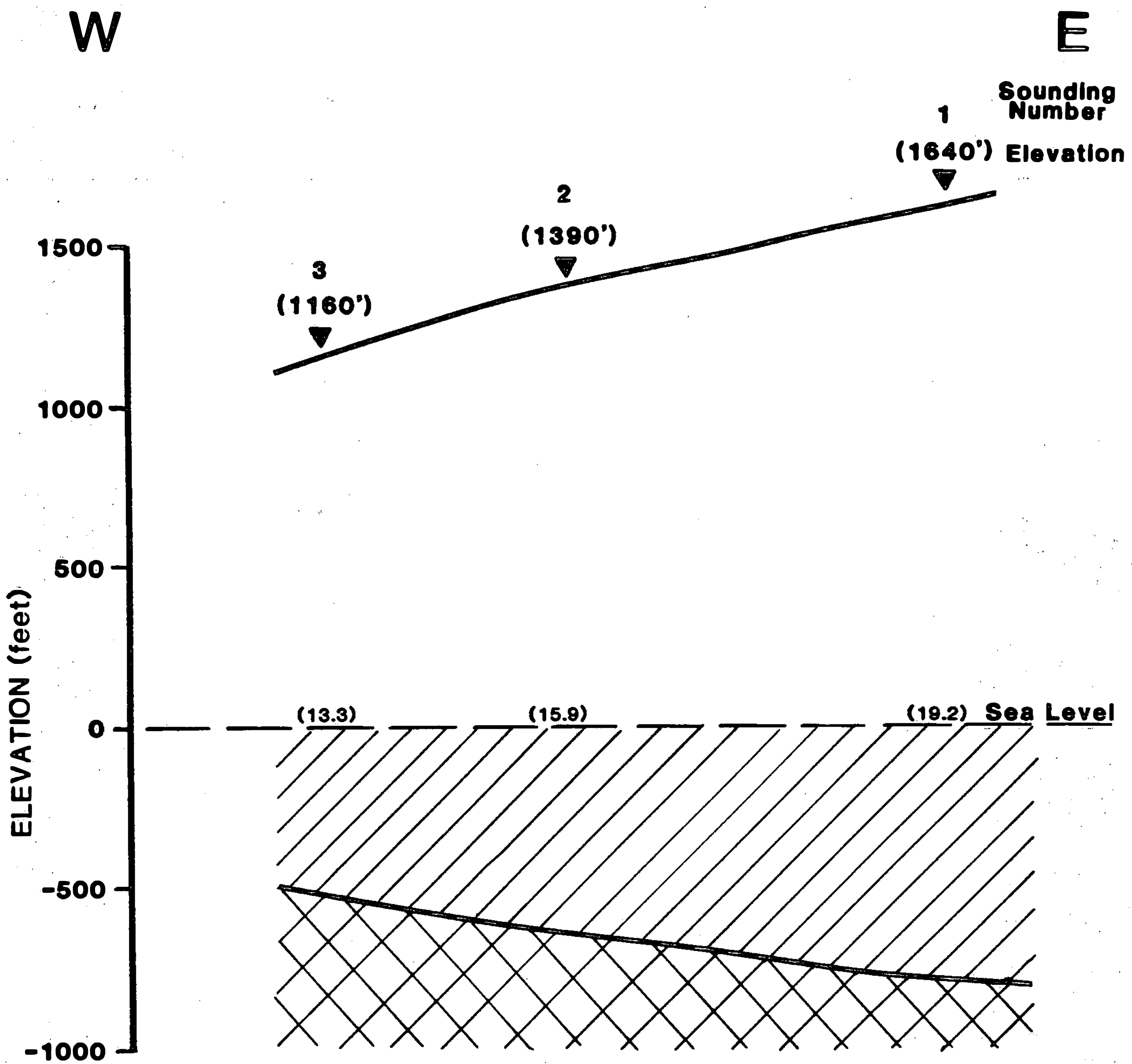
GEOELECTRIC CROSS SECTION
FROM TDEM INTERPRETATION

Kamehameha Schools/Bishop Estate

PROJECT NO.: 90015

FIGURE 4-1



Fresh/Brackish Water

Salt Water

(15.9) Calculated Elevation of Top of Fresh/Brackish Water

VERTICAL EXAGERATION 2 TO 1

1000 0 1000

SCALE - FEET

BLACKHAWK GEOSCIENCES, INC.

HYDROGEOLOGIC CROSS SECTION FROM TDEM INTERPRETATION

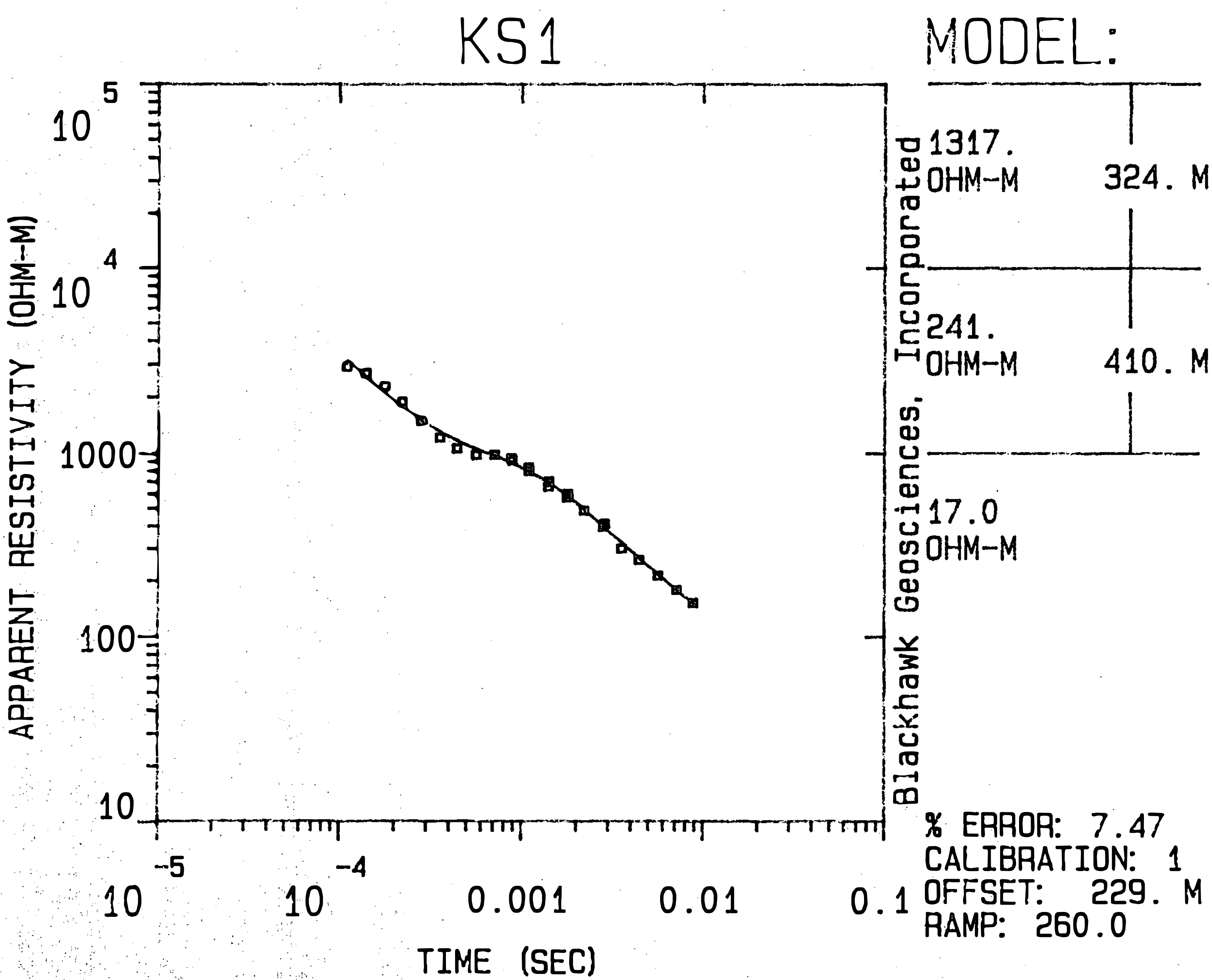
Kamehameha Schools/Bishop Estate

PROJECT NO.: 90015 **FIGURE 4-2**

5.0 CONCLUSIONS AND RECOMMENDATIONS

The TDEM survey indicates that in the area covered by soundings 1, 2 and 3 the largest thickness of fresh/brackish water lens occurs beneath sounding 1 (thickness of approximately 787 ft). At this station the head of fresh/brackish water is expected to be about 19 ft. The resistivities of the lower layer ranges from 17.0 to 7.5 ohm-m.

The geoelectric section for the three soundings (Fig. 4-1) shows that beneath soundings 1, 2 and 3 an intermediate resistivity unit was detected. This unit is expected to be caused by fresh/brackish water saturated ash flows or altered volcanics or ash flows within the volcanics, which may affect permeability and subsequently ground water yield. A slight possibility exists that the unit may be caused by an increase in salinity.


KS1
MODEL:
APPARENT RESISTIVITY (OHM-M)
TIME (SEC)
10^5
10^4
1000
100
10
10^-5
10^-4
0.001
0.01
0.1
1317.
OHM-M
324. M
241.
OHM-M
410. M
17.0
OHM-M
Blackhawk Geosciences, Incorporated
% ERROR: 7.47
CALIBRATION: 1
OFFSET: 229. M
RAMP: 260.0

MODEL: 3 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		499.9	1640.0		
1317.37	323.7	176.2	578.1	0.2	0.2
240.95	410.2	-234.0	-767.7	1.7	1.9
16.98					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	1.10E-04	2.90E+03	3.13E+03	-7.411	
2	1.40E-04	2.67E+03	2.54E+03	5.234	
3	1.77E-04	2.28E+03	2.09E+03	8.859	
4	2.20E-04	1.88E+03	1.77E+03	6.312	
5	2.80E-04	1.49E+03	1.49E+03	-0.297	
6	3.55E-04	1.21E+03	1.29E+03	-6.543	
7	4.43E-04	1.06E+03	1.16E+03	-8.337	
8	5.64E-04	9.71E+02	1.04E+03	-6.780	
9	7.13E-04	9.74E+02	9.62E+02	1.263	
10	8.81E-04	9.35E+02	8.83E+02	5.886	
11	8.90E-04	9.13E+02	8.79E+02	3.802	
12	1.10E-03	8.32E+02	7.91E+02	5.277	
13	1.10E-03	7.96E+02	7.89E+02	0.927	
14	1.40E-03	6.54E+02	6.89E+02	-5.144	
15	1.41E-03	6.99E+02	6.86E+02	1.899	
16	1.77E-03	5.72E+02	5.84E+02	-2.016	
17	1.80E-03	5.97E+02	5.78E+02	3.387	
18	2.20E-03	4.84E+02	4.88E+02	-0.970	
19	2.80E-03	3.97E+02	3.96E+02	0.368	
20	2.85E-03	4.12E+02	3.90E+02	5.690	
21	3.55E-03	3.00E+02	3.23E+02	-6.877	
22	4.43E-03	2.60E+02	2.66E+02	-2.116	
23	5.64E-03	2.14E+02	2.16E+02	-0.891	
24	7.13E-03	1.79E+02	1.78E+02	0.513	
25	8.81E-03	1.52E+02	1.50E+02	1.143	

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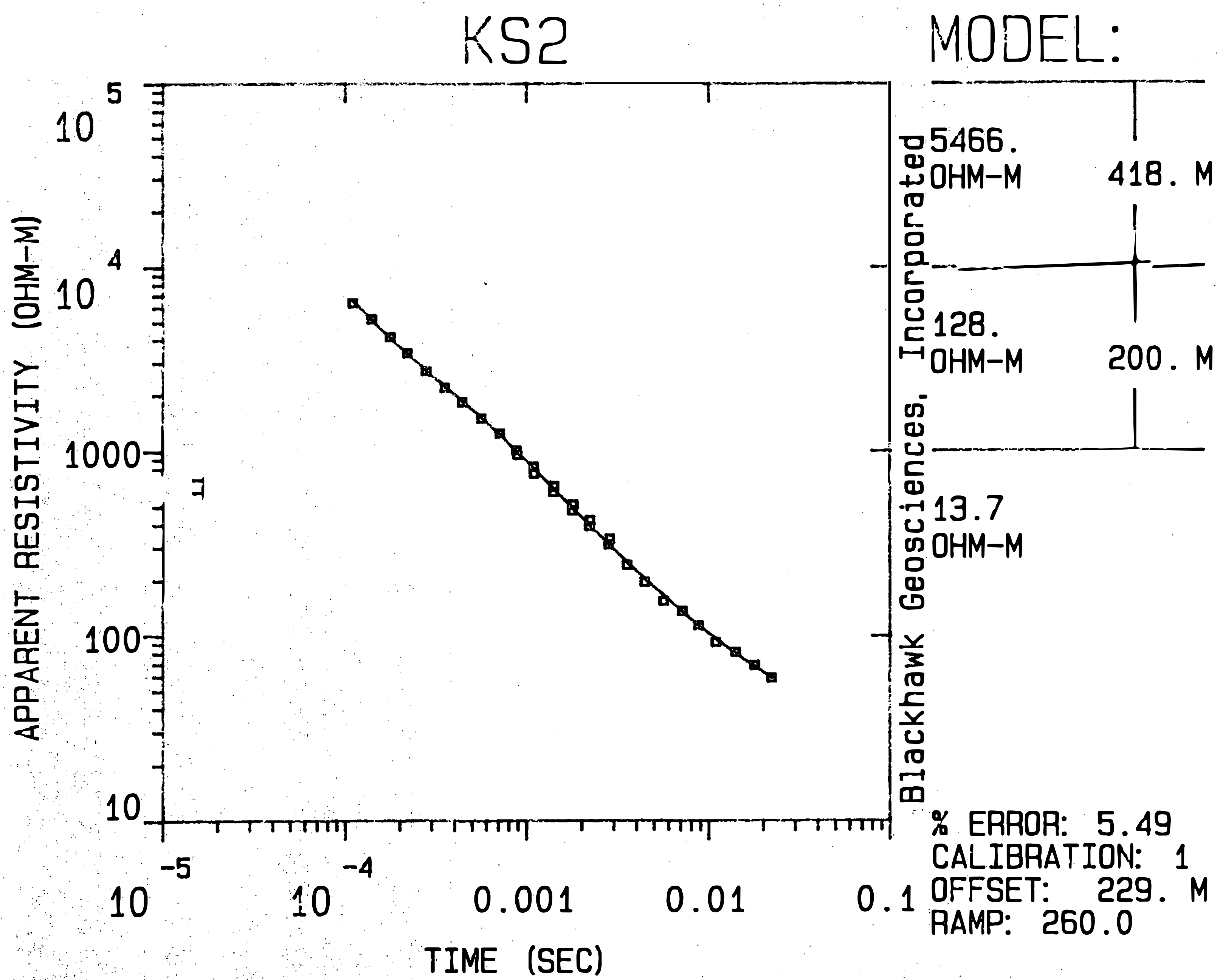
Ch.21 = 0.26 Ch.22 = 0.89 Ch.23 = 18.5 Ch.24 =
RMS LOG ERROR: 3.13E-02, ANTILOG YIELDS 7.4746 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.29				
P 2	-0.07	0.51			
P 3	0.04	-0.13	0.17		
T 1	0.23	0.25	-0.02	0.76	
T 2	-0.17	-0.16	0.01	0.15	0.82
	P 1	P 2	P 3	T 1	T 2


KS2
MODEL:
5466.
OHM-M
418. M
128.
OHM-M
200. M
13.7
OHM-M
Blackhawk Geosciences, Incorporated
APPARENT RESISTIVITY (OHM-M)
10^5
10^4
1000
100
10
10^{-5}
10^{-4}
0.001
0.01
0.1
TIME (SEC)
% ERROR: 5.49
CALIBRATION: 1
OFFSET: 229. M
RAMP: 260.0

MODEL: 3 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		423.7	1390.0		
5465.58	418.3	5.4	17.7	0.1	0.1
127.56	199.8	-194.4	-637.9	1.6	1.6
13.65					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	1.10E-04	1.61E-01	1.51E-01	6.302	
2	1.40E-04	1.19E-01	1.22E-01	-1.961	
3	1.77E-04	9.32E-02	9.55E-02	-2.491	
4	2.20E-04	7.33E-02	7.48E-02	-1.912	
5	2.80E-04	5.61E-02	5.57E-02	0.765	
6	3.55E-04	4.23E-02	4.14E-02	2.331	
7	4.43E-04	3.19E-02	3.14E-02	1.629	
8	5.64E-04	2.37E-02	2.34E-02	1.326	
9	7.13E-04	1.75E-02	1.81E-02	-3.123	
10	8.81E-04	1.41E-02	1.45E-02	-2.711	
11	8.90E-04	1.50E-02	1.44E-02	4.417	
12	1.10E-03	1.11E-02	1.16E-02	-4.195	
13	1.10E-03	1.26E-02	1.16E-02	8.500	
14	1.40E-03	9.72E-03	9.14E-03	6.285	
15	1.41E-03	8.51E-03	9.07E-03	-6.148	
16	1.77E-03	7.62E-03	7.25E-03	5.033	
17	1.80E-03	6.57E-03	7.16E-03	-8.117	
18	2.20E-03	5.97E-03	5.84E-03	2.122	
19	2.22E-03	5.18E-03	5.78E-03	-10.449	
20	2.80E-03	4.57E-03	4.55E-03	0.421	
21	2.85E-03	3.93E-03	4.47E-03	-12.021	
22	3.55E-03	3.68E-03	3.52E-03	4.571	
23	4.43E-03	2.92E-03	2.76E-03	5.931	
24	5.64E-03	2.29E-03	2.07E-03	10.354	
25	7.13E-03	1.52E-03	1.55E-03	-1.890	
26	8.81E-03	1.18E-03	1.18E-03	-0.328	
27	1.10E-02	9.33E-04	8.79E-04	6.179	
28	1.41E-02	5.97E-04	6.19E-04	-3.517	
29	1.80E-02	4.19E-04	4.32E-04	-2.972	
30	2.22E-02	3.11E-04	3.10E-04	0.311	

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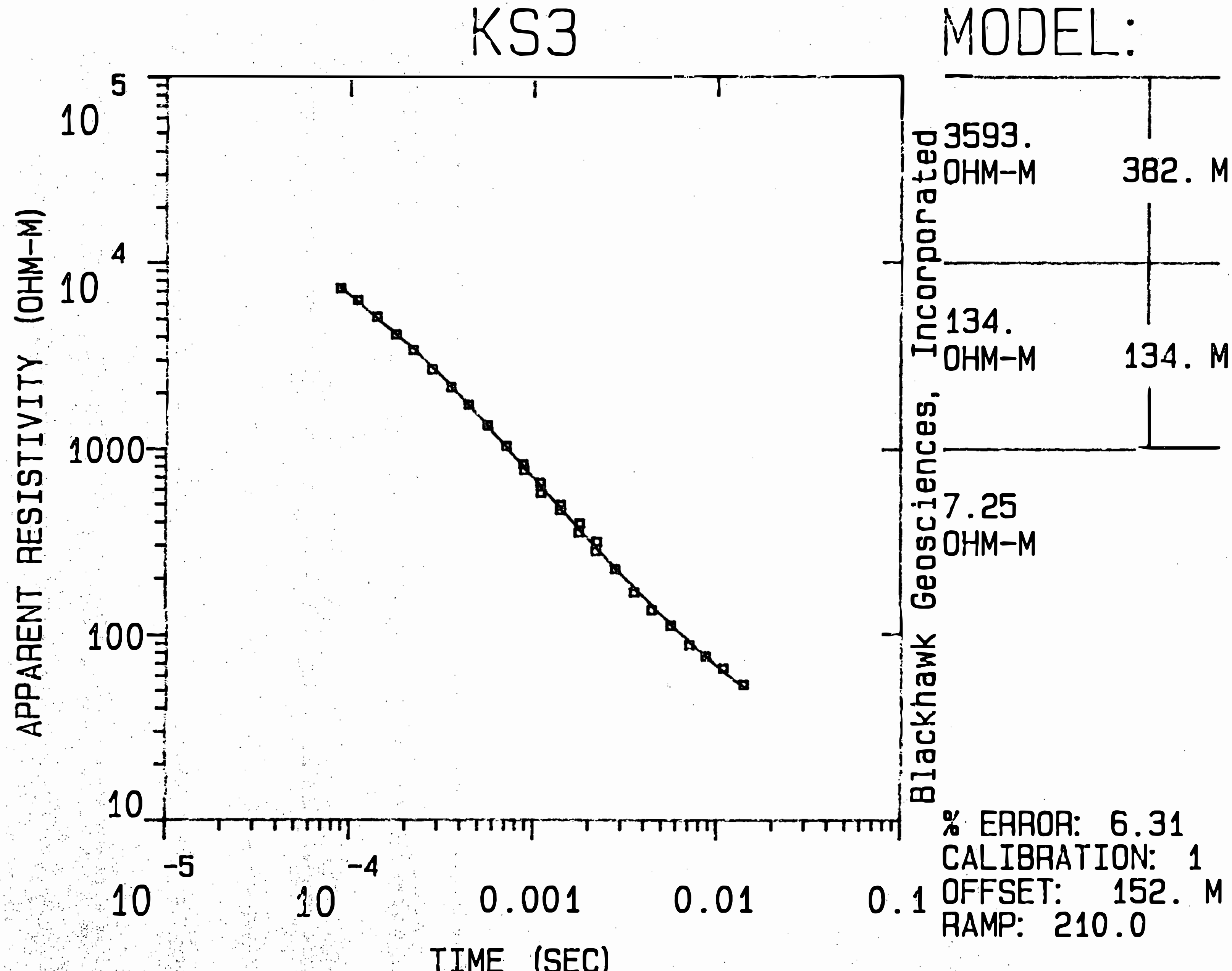
Ch.21 = 0.26 Ch.22 = 0.089 Ch.23 = 18.5 Ch.24 =
RMS LOG ERROR: 2.32E-02, ANTILOG YIELDS 5.4948 %
EARLY TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.85				
P 2	-0.04	0.98			
P 3	0.00	0.00	1.00		
T 1	0.01	0.01	0.00	1.00	
T 2	-0.03	-0.01	0.00	0.00	0.99
	P 1	P 2	P 3	T 1	T 2


KS3
MODEL:
APPARENT RESISTIVITY (OHM-M)
10^5
10^4
1000
100
10
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)
Blackhawk Geosciences, Incorporated
3593. OHM-M
382. M
134. OHM-M
134. M
7.25 OHM-M
% ERROR: 6.31
CALIBRATION: 1
OFFSET: 152. M
RAMP: 210.0

MODEL: 3 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		353.6	1160.0		
3592.51	382.3	-28.8	-94.4	0.1	0.1
134.37	133.5	-162.3	-532.5	1.0	1.1
7.25					

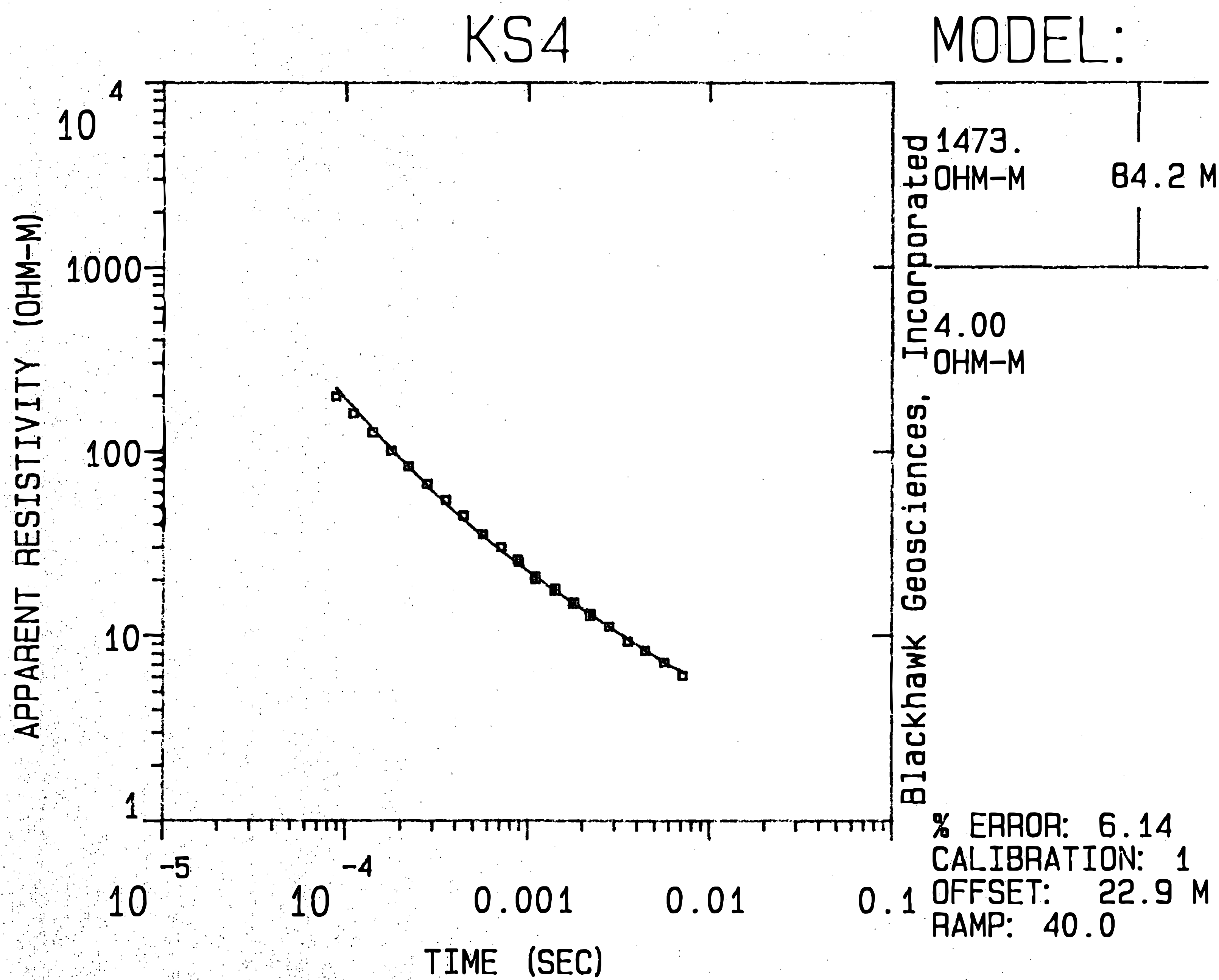
	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	7.27E+03	7.34E+03	-1.050	
2	1.10E-04	6.27E+03	6.11E+03	2.638	
3	1.40E-04	5.14E+03	5.00E+03	2.710	
4	1.77E-04	4.13E+03	4.14E+03	-0.281	
5	2.20E-04	3.40E+03	3.45E+03	-1.307	
6	2.80E-04	2.68E+03	2.76E+03	-2.982	
7	3.55E-04	2.15E+03	2.18E+03	-1.283	
8	4.43E-04	1.73E+03	1.73E+03	0.516	
9	5.64E-04	1.34E+03	1.32E+03	1.863	
10	7.13E-04	1.04E+03	1.01E+03	2.519	
11	8.81E-04	8.22E+02	7.96E+02	3.245	
12	8.90E-04	7.65E+02	7.87E+02	-2.760	
13	1.10E-03	6.53E+02	6.23E+02	4.714	
14	1.10E-03	5.73E+02	6.21E+02	-7.756	
15	1.40E-03	4.64E+02	4.75E+02	-2.240	
16	1.41E-03	4.95E+02	4.70E+02	5.195	
17	1.77E-03	3.50E+02	3.67E+02	-4.643	
18	1.80E-03	3.93E+02	3.62E+02	8.755	
19	2.20E-03	2.80E+02	2.91E+02	-3.889	
20	2.22E-03	3.14E+02	2.88E+02	8.886	
21	2.80E-03	2.24E+02	2.26E+02	-0.798	
22	3.55E-03	1.68E+02	1.78E+02	-5.388	
23	4.43E-03	1.36E+02	1.43E+02	-5.019	
24	5.64E-03	1.13E+02	1.14E+02	-0.996	
25	7.13E-03	8.84E+01	9.22E+01	-4.089	
26	8.81E-03	7.73E+01	7.65E+01	1.032	
27	1.10E-02	6.66E+01	6.37E+01	4.512	
28	1.41E-02	5.43E+01	5.23E+01	3.870	

R: 152. X: 0. Y: 153. DL: 305. REO: 170. CF: 1.0000
TDHZ ARRAY, 28 DATA POINTS. RAMP: 210.0 MICROSEC, DATA: KS3
0304 0003 0003 Z OPR XTL H 6 8+100
Ch.21 = 0.21 Ch.22 = 0.089 Ch.23 = 20.5 Ch.24 =
RMS LOG ERROR: 2.66E-02, ANTILOG YIELDS 6.3050 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.87				
P 2	-0.11	0.83			
P 3	-0.02	-0.03	0.99		
T 1	0.02	0.03	0.00	1.00	
T 2	-0.06	-0.08	-0.01	0.01	0.96
	P 1	P 2	P 3	T 1	T 2



KS4
MODEL:
1473.
OHM-M
84.2 M
4.00
OHM-M
Blackhawk Geosciences, Incorporated
APPARENT RESISTIVITY (OHM-M)
TIME (SEC)
% ERROR: 6.14
CALIBRATION: 1
OFFSET: 22.9 M
RAMP: 40.0

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		73.2	240.0		
1472.74	84.2	-11.0	-36.1	0.1	0.1
4.00					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	1.98E+02	2.19E+02	-9.796	
2	1.10E-04	1.60E+02	1.72E+02	-6.973	
3	1.40E-04	1.26E+02	1.32E+02	-4.329	
4	1.77E-04	1.01E+02	1.03E+02	-1.747	
5	2.20E-04	8.28E+01	8.22E+01	0.773	
6	2.80E-04	6.68E+01	6.47E+01	3.247	
7	3.55E-04	5.46E+01	5.18E+01	5.459	
8	4.43E-04	4.47E+01	4.25E+01	5.268	
9	5.64E-04	3.54E+01	3.45E+01	2.532	
10	7.13E-04	3.02E+01	2.87E+01	5.360	
11	8.81E-04	2.59E+01	2.43E+01	6.476	
12	8.90E-04	2.50E+01	2.41E+01	3.622	
13	1.10E-03	2.08E+01	2.07E+01	0.484	
14	1.10E-03	2.01E+01	2.07E+01	-2.813	
15	1.40E-03	1.74E+01	1.75E+01	-0.565	
16	1.41E-03	1.80E+01	1.74E+01	3.376	
17	1.77E-03	1.48E+01	1.49E+01	-0.635	
18	1.80E-03	1.51E+01	1.48E+01	2.517	
19	2.20E-03	1.28E+01	1.30E+01	-1.548	
20	2.22E-03	1.32E+01	1.29E+01	2.204	
21	2.80E-03	1.11E+01	1.11E+01	0.544	
22	3.55E-03	9.24E+00	9.52E+00	-2.953	
23	4.43E-03	8.24E+00	8.26E+00	-0.290	
24	5.64E-03	7.11E+00	7.12E+00	-0.152	
25	7.13E-03	6.09E+00	6.37E+00	-4.322	

R: 23. X: 0. Y: 23. DL: 46. REQ: 26. CF: 1.0000
TDHZ ARRAY, 25 DATA POINTS, RAMP: 40.0 MICROSEC, DATA: KS4
0104 0000 0000 Z OPR XTL H 5 8+100
Ch.21 = 0.04 Ch.22 = 0.089 Ch.23 = 16 Ch.24 = 2
RMS LOG ERROR: 2.59E-02, ANTILOG YIELDS 6.1405 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.00		
P 2	0.00	0.05	
T 1	0.00	0.08	0.48
	P 1	P 2	T 1